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National Center for Radiological Health
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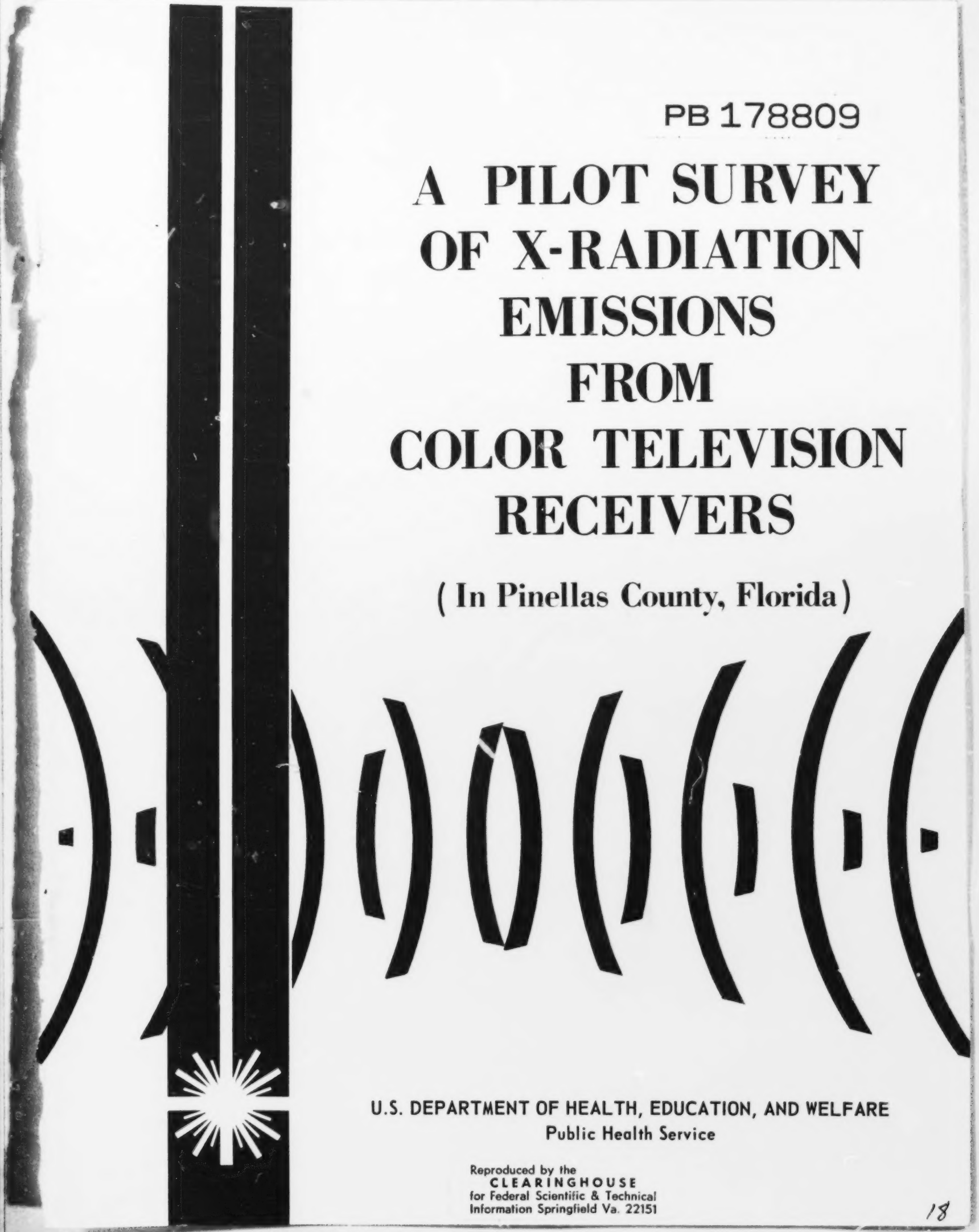

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service

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TSB NO. 2

A PILOT SURVEY OF X-RADIATION EMISSIONS FROM COLOR TELEVISION RECEIVERS

(In Pinellas County, Florida)

TECHNICAL SERVICES BRANCH
Electronic Products Radiation Laboratory
Staff Report

D. Smith, R. Schneider, J. Steiner

June, 1968

U. S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service
Bureau of Disease Prevention and Environmental Control
National Center for Radiological Health
Rockville, Maryland 20852

FOREWORD

This report describes a pilot survey conducted in Pinellas County, Florida, in November 1967, to evaluate methodology and techniques for use in determining the effectiveness of the General Electric Company's color television receiver modification program and in assessing the total radiation emission situation for television sets of all manufacturers. The primary objective of this survey was to evaluate the effectiveness of the Company's modification program to replace shunt regulator tubes which were emitting radiation in a downward beam. Within the limits of this survey, the General Electric downward beam modification program was found effective, and data on other possible sources of X-radiation emission were collected. The survey was the basis for testimony to this effect before the Subcommittee on Public Health and Welfare of the House Subcommittee on Interstate and Foreign Commerce on February 1, 1968.

The second objective of this pilot survey was to evolve and test new instruments and new methods of measurement for surveys of television sets produced by other manufacturers. The instrument used to measure X-rays from color television receivers was designed by the National Center for Radiological Health to facilitate rapid home surveys. The source, size, shape and intensity of emissions were documented by radiographic films that were exposed on selected receivers.

A broader survey was later conducted in the Washington, D. C. Metropolitan Area. A conference on Detection and Measurement of X-radiation from Color Television Receivers was then held on March 28-29, 1968. Each event contributed to the advancement of the art of measurement.

James G. Terrill, Jr.
Center Director

INTRODUCTION

In the spring of 1967, the General Electric Company undertook a program to modify approximately 110,000 large screen color receivers by replacement of high voltage shunt regulator tubes. The object of the modification program was to correct a downward emission of X-radiation. The source of the radiation was found to be the high voltage shunt regulator tube. The Company reported that practically all of the sets had been modified by the summer of 1967.

Following notification of the problem and the modification program by General Electric, the Public Health Service investigated the X-radiation emission from regulator tubes used in color television receivers (1,2). The studies described the measured X-ray distributions in direction, quality and intensity from the shunt regulator tube.

The Public Health Service indicated to the House Sub-committee on Public Health and Welfare of the House Committee on Interstate and Foreign Commerce (3) and to the Senate Commerce Committee (4) that the effectiveness of the modification program should be verified through laboratory and field tests efforts by the National Center for Radiological Health.

The local arrangements for the survey were made by George McCall, Health Physicist, Pinellas County Health Department and Mr. D.J. Nelson, Assistant Director for Laboratories, who served as the overall director of the project. Members of Mr. McCall's staff, Mr. Clyde Stagner and Mr. Dale Rees, served as the survey team leaders. Mrs. Russell Hobbs, PCHD, arranged the appointments for the surveys in the homes. Mr. Roger Schneider, EPRL, was the project coordinator for the NCRH in Pinellas County, and Mr. Donald Smith was the project officer. The NCRH personnel participating in the surveys were Mr. Richard Stoms, Mr. Thomas Lee, Mr. John Steiner, Mr. Richard Wromble, and Mr. Charles Warr.

This report describes participation of the National Center for Radiological Health with the Pinellas County Health Department in a pilot survey conducted in November 1967.

Survey Design

The NCRH made arrangements in October 1967 with the Pinellas County Health Department to conduct a joint survey to test the methods and procedures required for X-radiation surveys of home color television receivers. Pinellas County, Florida was selected as the site for the survey because of the county's special interest in the problem and previous efforts to achieve control over the X-ray emissions from this source. The specific objectives of the survey were: (1) to check the results of the modification program carried out by the General Electric Company on certain large-screen color television sets in Pinellas County; (2) to evaluate methodology and techniques applicable to a more extensive evaluation of the downward beam of the shunt regulator tubes; and, (3) as far as possible, to develop techniques for the assessment of the total X-radiation emission situation for sets of all manufacturers.

The manufacturer had distributed color television sets in Pinellas County potentially capable of emitting X-rays in excess of the 1960 recommendation of the National Council on Radiation Protection, that "the exposure rate at any readily accessible point 5 cm from the surface of any home television receiver shall not exceed 0.5 mR per hour under normal operating conditions". The Company had modified those color television sets already purchased and in homes, by having local servicemen

replace the high voltage shunt regulator tubes (type 6EA4, 6EF4, or 6LC6) originally in the receivers with improved tubes (type 6EH4, 6EJ4, or 6LH6) and by readjusting the regulated high voltage supply to the cathode ray tube. The service representatives were not equipped to measure X-rays.

Estimates of the X-radiation exposure rates from the television receivers in the home were obtained by scanning the exterior surfaces of the set with a radiation-sensitive large-area Geiger type survey meter. To further document the source, size, shape and intensity of emissions, radiographic films were exposed on one or more surfaces of selected receivers having higher radiation emissions (Fig. 1). The films were then sent to the National Center for Radiological Health Headquarters in Rockville, Maryland, where they were developed and analyzed, visually and by optical density measurements. A detailed description of the procedure is given in TSB #3 (Ref. 6).

The manufacturer's technical personnel who accompanied the survey teams provided technical assistance and followup, including the adjustment of operating high voltage and the replacement of receiving tubes when this was necessary to reduce X-ray emission. The shunt regulator tube in each receiver was replaced by an improved version of the tube designated 6EH4A, 6EJ4A or 6LH6A as appropriate to each individual set. This exchange program was undertaken to provide the National Center for Radiological Health with a sample of the tubes for use in laboratory tests.

Instrumentation

The instruments used in the survey were designed and constructed by Mr. Richard K. Stoms (Ref. 5), National Center for Radiological Health, expressly for surveys of radiation from TV receivers and received its initial test in the field in Pinellas County. The radiation sensitive element of this instrument is an array of six Victoreen type 1B85 Geiger-Mueller counters. They are connected to a common high voltage supply. Individual solid state circuits measure the current through each counter. The outputs of these counter readout circuits are connected to the input of the circuit in such a manner that the meter indicates only the reading of the counter with the highest output. This connection has the sensitive area of one counter for calibration. The large sensitive detection area provided by the six tubes allowed a surveyor to make a complete traverse of all set surfaces in ten minutes. The instrument was easily handled in any position by one person. The location and approximate size of radiation beams could be estimated by depressing a switch which turned off all detector tubes except the end one.

Since the primary objective of the survey was to check the results of the modification program, instruments were calibrated using a downward emission from a shunt regulator tube. Using this calibration, a meter reading of 4000 on the instrument was equated to 0.5 milliroentgen per hour (mR/hr), with the calibration source operated at 25 kV and the X-ray beam adjusted by means of aluminum absorbers to have a first half-value layer of 0.5 mm of aluminum.

During the initial survey operation, current leakage across the bases of the GM survey counters, due to humidity, caused high background counting

rates. The problem was solved by thoroughly drying the bases of the 1P85 detectors and then encapsulating them with silicone rubber.

Survey Procedures

The necessary local arrangements for visits to the set owners were made by Dr. John T. Obenschain, Director, Pinellas County Health Department and Mr. George McCall, Public Health Physicist, Pinellas County Health Department. All known modified receivers in the County were listed in alphabetical order by name of the owner and each set was assigned a code number. An introductory letter issued by the County Health Department was sent to each set owner describing the purpose of the survey. Appointments were arranged in advance by telephone. In instances where the set owners could not be reached by telephone the survey teams called in person to request permission to make the survey.

Surveys of the television receivers in the homes were conducted by three teams. Each team consisted of Public Health Service, Pinellas County, and a manufacturer's representative. On entering the home, the householder was asked to turn the set on and obtain a normal operation picture. The manufacturer's representative observed the picture on the set and made a determination of whether or not the set operation appeared normal. The team surveyed the set on all sides, top and bottom for X-ray emissions. Succeeding steps depended upon the conditions found, which were classified into one of four categories as follows:

A. Condition 1 - Set operation appears normal - Instrument reading less than 4000 (0.5 mR/hr) meter reading

(1) Serviceman measured line voltage, survey of set was made, and team leader recorded reading.

(2) Serviceman replaced shunt regulator tube and adjusted anode voltage.

(3) Team leader recorded tube type and properly identified old tubes with the set.

(4) Set was turned on and readjusted.

(5) A resurvey was made and radiation levels noted on report forms.

B. Condition 2 - Set operation appears normal - Instrument readings at or above 4000

(1) Serviceman measured line voltage.

(2) Team leader made judgment on use of film after consultation with owner.

(3) When used, film was applied by tape to the identified area or areas of maximum emission. Film was identified by set code number.

(4) When used, film was removed at prearranged time that provided an estimated time of operation, or a timer was connected to the set.

(5) Serviceman measured line voltage and anode voltage, replaced tube(s) (shunt regulator and/or high voltage rectifier) identified as source(s) of emission, reset anode voltage and readjusted picture.

(6) Team leader resurveyed the set and recorded the information.

C. Condition 3 - Set operation appears abnormal - Instrument reading less than 4000

(1) Serviceman designated the probable cause of any malfunction.

(2) Team leader asked the owner to observe the picture, asked whether or not he had noticed any difficulty, whether or not he regularly used the set, and whether or not the set had been repaired or adjusted since the modifications were completed.

(3) The survey was continued as for Condition 1.

D. Condition 4 - Set operation appears abnormal - Instrument reading at or above 4000

(1) Proceeded per (1) and (2) under Condition 3.

(2) Proceeded per (1) through (6) under Condition 2.

(3) In the event that readings above 4000 were observed after completing the survey the team leader advised the owner that servicing was needed and recommended distances and viewing positions to viewer to limit radiation exposure. After servicing was reported by owner as having been completed, a resurvey of the set was made.

In some instances measurements were also made with the set brightness adjusted to the darkest usable picture to indicate whether or not the shunt regulator tube was the primary source of radiation.

It took approximately 30 minutes to complete a survey. In Pinellas County the visits were arranged so that the teams were working within a small geographical area of the County at any given time. This kept travel time between surveys at a minimum. Each survey team working full time, was able to complete approximately seven surveys per day.

Information Recorded

For each set the model number and serial number were recorded. In addition to the radiation levels measured for each set, estimates of the size of the radiation field and location of the center of the radiation field on the set surfaces were entered on the survey form. Information concerning the date of modification and any servicing since modification was recorded. For each set a determination and record was made by the team leader as to whether or not the set indicated a 4000 reading on the survey instrument. Where film packs were used the film pack identification number and the exposure time were recorded.

The Public Health Service personnel participated in surveys of 143 sets and the County personnel completed surveys of five additional sets. Ten other sets could not be surveyed for the following reasons: one refusal, eight sets could not be located or had been moved from the County, and one set was returned for service and repair. The sets surveyed included four "B" model chassis and one "D" model chassis. These are models of color television sets which were not included in the Company's modification program, but, possibly, contained the same types of rectifier and shunt regulator tubes.

Using the instrument calibration and assumptions previously discussed the recorded data were converted to mR/hr and presented in Tables 1 and 2. Table 1 shows the number of color television receivers by X-radiation exposure rate and operating high voltage. The line voltage was found to vary from 110 to 127 Volts. The anode voltage measured ranged from 19 kV to

over 30 kV (the shunt regulator tube voltage is about 400 Volts lower). The location of maximum X-radiation exposure rates on home color television receivers is shown in Table 2.

Discussion

(1) No instances were detected of either downward or frontward radiation in excess of 0.5 mR/hr. Where levels of emission were detected they appeared to be from sources that could be associated with the sets of all manufacturers (7). The location of radiation emission from the surfaces of the television receivers indicated that X-rays from the high voltage rectifier tube as well as from the shunt regulator tube were a significant factor. Patterns identified by 16 radiographic films exposed on television receivers in Pinellas County suggest the rectifier tube as a probable primary source of lateral X-ray emission. In 11 receivers replacement of the rectifier tube reduced X-ray emissions.

(2) The operating high voltage, in the majority of the sets surveyed was above the value recommended for the chassis by the manufacturer at the line voltage encountered. Since an extensive modification program had been performed in Pinellas County and instructions had been given to the repairmen on the proper voltage setting, it was not expected that these high operating voltages would be found. Therefore, high operating voltages may be a major cause of the excessive exposure rates from the high voltage rectifier tubes. The effect of varying the high voltage on the X-ray emission from the rectifiers is illustrated below by the measurements made on one receiver in the survey:

kV	mR/hr
27	10
26	5
25	3
24	1
23	0.53

It was also noted that in many cases X-radiation emission was reduced when the high voltage was adjusted to the level recommended by the manufacturer. Laboratory tests conducted by the National Center for Radiological Health have shown that excessive operating voltage can result in increased X-radiation emission from tube components (1,2).

(3) A resurvey of the sets after the corrective servicing showed the X-ray exposure rates from all sets to be within the recommended level of 0.5 mR/hr. A service adjustment was made to each set in Pinellas County where the survey instrument indicated exposure rates above 0.5 mR/hr. The adjustment included exchange of the shunt regulator tube, exchange of the high voltage rectifier tube, and adjustment of the operating high voltage. Appropriate tube replacement and/or proper high voltage adjustment reduced X-radiation wherever required.

(4) Incidental to the survey a 6EA4 tube was found in a "B" model chassis. This model of the General Electric television receiver was not included in the GE modification program. A radiation level was observed at the side of the set to the viewers left. An exchange of the shunt regulator tube, and a voltage adjustment corrected this radiation problem. High radiation levels from the "B" model may indicate an evaluation of earlier production models and of models produced by other manufacturers is necessary to insure excessive X-ray emissions do not exist from the shunt regulator in these sets.

Conclusions

(1) In the sets surveyed and within the limits of the survey instrument used, the problem of downward directed X-ray leakage had been corrected by replacement of the original high voltage shunt regulator tubes (type 6EA4, 6EF4, 6LC6) with replacement tubes (6EH4, 6EJ4, or 6LH6) and in the later stages of the modification program with the "A" version of these tubes. The review of the survey reports for 148 sets showed only two sets with a measurable radiation level at the bottom of the set. The survey instrument readings indicated these levels for the two receivers were below 0.5 mR/hr.

(2) The high voltage rectifier appeared to be the major source of the radiation detected. In many cases the emission was in part due to a high voltage setting above that recommended by the manufacturer for these receivers.

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5. Instrument for Measurement of X-Ray Emission from Television Sets. R. K. Stoms and Edward Kuerze, Technical Papers, Conference on Detection and Measurement of X-Radiation from Color Television Receivers, March 1968.

6. A Survey of X-Radiation from Color Television Sets in the Washington, D.C. Metropolitan Area. Technical Services Branch, National Center for Radiological Health, TSB Report No. 3.

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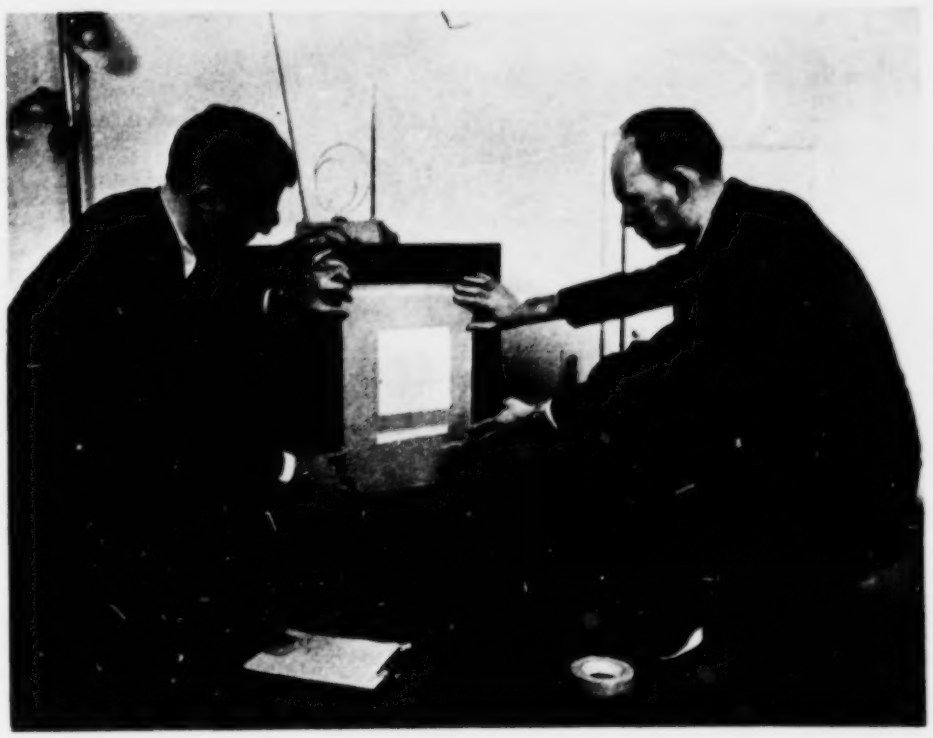
FIGURE 1

Photographs illustrating the measurement of X-radiation emissions from color televisions

A. The Public Health Service developed a survey instrument for measuring X-rays from each surface of the color television receiver.



B. Radiographic film was used to document size, shape and possible source of the X-radiation emission.

TABLE I

Number of Color TV Receivers by X-Radiation Exposure Rate and Operating High Voltage

X-Radiation Exposure Rate mR/hr	TOTAL	OPERATING HIGH VOLTAGE (kilovolts)										
		21	22	23	24	25	26	27	28	29	30	Unknown
TOTAL	148	3	6	8	39	55	18	5	1	1	1	11
< 0.040	54	3	6	4	16	15	3	0	0	0	0	7
0.040 - 0.074	5	0	0	1	2	1	1	0	0	0	0	0
0.075 - 0.124	2	0	0	0	0	0	2	0	0	0	0	0
0.125 - 0.249	21	0	0	0	6	12	2	1	0	0	0	0
0.250 - 0.499	23	0	0	3	6	12	1	0	0	0	0	1
0.500 - 0.999	21	0	0	0	3	6	7	3	0	0	0	2
1.000 - 1.999	15	0	0	0	4	7	2	0	1	0	0	1
2.000 - 3.749	1	0	0	0	1	0	0	0	0	0	0	0
3.750 - 7.499	4	0	0	0	1	2	0	1	0	0	0	0
7.500 - 12.500	0	0	0	0	0	0	0	0	0	0	0	0
> 12.500	2	0	0	0	0	0	0	0	0	1	1	0
% exceeding 0.5 mR/hr		0	0	0	23.1	27.3	50.0	80.0	100.0	100.0	100.0	27.3

TABLE II

Location of Maximum X-Radiation Exposure Rates on Home Color TV Receivers

X-Radiation Exposure Rates mR/hr	TOTAL	Number of Sets by Location of the Highest Exposure Rate Measurement*					
		Bottom	Left	Top	Front	Right	Back
TOTAL	94	0	74	1	2	0	17
0.040 - 0.074	5	0	2	0	0	0	3
0.075 - 0.124	2	0	1	0	1	0	0
0.125 - 0.249	21	0	17	0	1	0	3
0.250 - 0.499	23	0	18	1	0	0	4
0.500 - 0.999	21	0	18	0	0	0	3
1.000 - 1.999	15	0	11	0	0	0	4
2.000 - 3.749	1	0	1	0	0	0	0
3.750 - 7.499	4	0	4	0	0	0	0
7.500 -12.499	0	0	0	0	0	0	0
> 12.500	2	0	2	0	0	0	0

*A number of sets had the same exposure-rate on more than one side. The priority for placement in the table is the following: front, left, top, back, bottom, and right. "Left" is the set surface on the viewer's left.